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Hazardous Areas: Classifications, Equipment, Purging, and Management

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TYPICAL PRODUCTS TO ENABLE MOUNTING OF ELECTRICAL EQUIPMENT IN HAZARDOUS AREAS

Intrinsic Safety Barriers

Intrinsic safety (IS) barriers limit the electrical energy available from wires going into a hazardous area, such that a spark from shorting the wires is not capable of igniting the hazardous atmosphere. Resistive (or "passive") barriers, with resistors, diodes, and a fuse (sometimes the fuse is replaceable), require earth grounding and add series resistance. Resistive barriers can have resistances in the range of about 40 Ω to about 750 Ω, and can support currents of up to about 400 mA, depending on the voltage rating and the group of the hazard. Electronic (or "active") barriers, containing active electronic circuits, do not require earth grounding, add only minimal or no series resistance, and are also available as repeaters to enable greater loop resistances. If using with a HART-enabled system, make sure that the barrier is specified as being compatible with HART™ (Highway Addressable Remote Transducer) communication, see Chapter 28.

Explosion Proof Housings

Explosion proof housings are usually cast aluminum, and can protect equipment that is not rated for hazardous area duty. Housings are available for all classes and groups of hazardous areas. If an explosion takes place within the housing, hot gases are sufficiently cooled before escaping, so that the cooled gases are not capable of igniting the environment outside of the housing.

Purging Equipment

Purged enclosures and purging control systems can be purchased or built for the application. Equipment that is not rated for hazardous area duty can sometimes be economically enclosed in an appropriate type of purged enclosure, depending on the type of equipment (e.g., non-incendive), on the division of the hazard (e.g., Division 1 or 2), on the class (e.g., gas is Class I, and so on), and on the group of the hazard (e.g., ethylene is group C, and so on).

INTRODUCTION

In the context of prevention of an industrial fire or explosion, a potentially hazardous area is defined as one in which electrical equipment is present and combustible materials may be present either continuously or intermittently. Hazardous area regulations for the United States are published in the National Electrical Code (NEC), which is also identified as ANSI/NFPA 70. Articles 500 through 506 of the NEC relate to classification of electrical installations in hazardous locations. Articles 510–517 relate to specific occupancies having potentially hazardous areas.

Combustible materials may include flammable gases, vapors, dust, fibers and flyings. When there is a likelihood of the presence of combustible materials, it is important to either reduce their concentration to a level that would be less than one capable of supporting combustion, or to prevent an ignition source from initiating a fire or explosion. Alternatively, the explosion or combustion products can be contained within a confined space (e.g., explosion-proof or flameproof housing) that prevents ignition of the areas outside of the containment. Sources of ignition can include arcing of an electrical circuit due to close proximity of wires, contacts opening or closing, or a loose wire touching another, and also can include electrostatic discharge or a high-temperature surface (e.g., a hotspot).

A flammable material is one that can easily catch fire upon initiation from an ignition source, such as a spark of sufficient energy density. Flammable materials include things like alcohol vapor, propane, gasoline vapor, and some particles or dusts suspended in air, etc. A combustible material, however, is any material that can burn. To exemplify the difference, combustible materials include the flammable materials mentioned above, plus wood, coal, some plastics, and other materials that can burn, but may not be so easily ignitable. Incidentally, the word inflammable has the same meaning as the word flammable.

A given "hazardous area" installation will have its own unique set of conditions to be considered, depending upon the hazardous materials present, the process, and associated equipment. It is always desirable to address all identifiable areas of potential risks, so that a safe working environment can be continuously maintained. Over the years, accidental occurrences of fires and explosions around the world have led to improvements in the systems for prevention of such accidents. With standardized procedures, it is expected that compliance with today's laws, rules, and regulations can provide freedom from such accidents when the rules are properly applied.

In order to correctly apply the laws, rules, and regulations, a hazardous area in question must first be classified according to its type and level of potential risk. Then, with regard to the manufacturing processes or other functions being conducted, the required equipment can be selected and appropriate protection methods can be determined, designed, and installed. In addition to the deployment of proper equipment, procedures must be documented, initial and ongoing safety training conducted, uniform compliance assured, and the systems must be maintained and checked according to proscribed preventive maintenance schedules.

Industrial equipment can be protected by various means, including IS, explosion proof/flameproof, grounding and bonding, purging, ventilation, encapsulation, oil or sand-filling, and other approved methods.

The various safety systems are described in and often become a part of national, state, and local laws. Compliance with regulations is tested and approved by several national and international testing agencies, whose approval stamps often must appear on the equipment. In the United States, the primary bodies for approval of equipment for use in hazardous areas are Underwriters Laboratories (UL) (www.ul.com) and Factory Mutual (FM) (www.fmglobal.com). There are also other independent companies that provide similar testing and verification. In Canada, the approval body is the Canadian Standards Association (CSA) (www.csa.ca). Countries belonging to the European Union (EU) have established "Notified Bodies" for product approval. Notified Bodies include British Approval Service for Electrical Equipment in Flammable Atmospheres (BASEEFA) in Great Britain, Physikalisch Technische Bundesanstalt (PTB, meaning "National Institute for Science and Technology") in Germany, Laboratorie Central des Industries Electriques (LCIE, meaning "Central Laboratory of the Electrical Industries") in France, Centro Elettrotecnico Sperimentale Italiano (CESI, meaning "Italian Experimental Electrotechnical Center") in Italy, and others. Product approvals by the notified bodies are also called Comité Européen de Normalisation Électrotechnique (CENELEC, which is French for the "European Committee for Electrotechnical Standardization") approvals. A product with CENELEC approval from any member country is accepted for use within all of the member countries. The ATmosphères EXplosibles (ATEX) Directive pertains to equipment for use in potentially explosive atmospheres, and all products for such use must comply with the ATEX Directive in order to be sold in the EU.

In Japan, the approval agency is Technology Institution of Industrial Safety (TIIS), Australia has Standards Association of Australia (SAA), and Russia has Gosstandart (GOST, i.e., the Russian State Committee of Standards).

DEFINITIONS

Equipment approved for use in hazardous areas is typically installed in places like fuelling stations, chemical plants, pharmaceutical production facilities, paint and ink manufacturing plants, oil and gas rigs, storage areas for flammable liquids, oil refineries; and there are many others. When a given hazardous area is classified, the classification indicates the level of risk, and can be used as a rule and guide in selecting equipment that is rated for use in areas having that particular type of classification. The nomenclature used in North America, compared with that used in Europe and generally in the rest of the world, have some differences, although they are based on the same theory and measurements. North America uses the division system, and most other areas of the world use the zone system, both explained later in this chapter.

To classify a hazardous area, one begins by identifying all combustible materials that may exist in the area, either for a manufacturing process, storage, or for any other reason or use. Next, the likelihood of the identified materials being present in sufficient quantity to support combustion is examined. Then, the conditions and equipment in the area are considered regarding their capacity of igniting the combustible materials, and under what conditions the combustible material and a capable source of ignition might come into contact or sufficient proximity for ignition. Regarding ignition sources, electrical equipment is the main area of attention, although a strong discharge of static electricity can also be an ignition source, especially if the spark comes from a sharp or pointed electrical conductor (such as a screwdriver).

The National Fire Protection Agency (NFPA) (www.NFPA.org) publishes various standards for classifying hazardous areas and for electrical equipment to be used in these areas. When classifying a hazardous area, it is often a simple matter to compare the gases and vapors of the process to Table 2.1 of NFPA 497, and to compare the dusts to Table 2.5 of NFPA 499. This will provide the class and group information. But selecting the applicable division, which indicates the likelihood of the flammable material being present, can become a more involved process. It is sometimes difficult to determine the likelihood of the presence of flammable mixtures in and around process equipment and storage areas. This determination requires the understanding of some of the physical properties of the liquid, vapor, or gas, including flash point, auto-ignition temperature, and upper and lower explosive limits.

Flash point of a liquid is the minimum temperature at which a liquid is capable of generating sufficient quantities of vapor, in air, at standard pressure, to be ignitable when exposed to an ignition source. If the pressure is higher than standard atmospheric pressure, then the flash point temperature may be lower. This dependence upon pressure also applies to the other limits, explained below.

Auto-ignition temperature is the minimum temperature at which a material, in air, at standard pressure, can spontaneously ignite without need for a spark or other ignition source.

Lower explosive limit (LEL) or *lower flammability limit* (LFL) and the *upper explosive limit* (UEL) or *upper flammability limit* (UFL) bound the range of concentrations of a gas or vapor mixture in air, at standard pressure, over which the mixture can be ignited with an ignition source. They are expressed as percent by volume in air. So, a mixture is ignitable when its concentration is above the LEL and below the UEL.

In North America, hazardous areas are traditionally classified according to Class, Division, and Group. But the zone classification system is also included in the NEC, and is more in line with International Electrotechnical Commission (IEC) (www.iec.ch) classifications. In much of the rest of the world, IEC and ATEX standards are used, having classifications of zone, group, and auto-ignition temperature. In order to address classification world-wide, both the traditional North American division standards and the zone classification standards according to the NEC are presented in this chapter.

NORTH AMERICAN HAZARDOUS AREA CLASSIFICATION STANDARDS

In North American hazardous area classification, there are three classes, according to which type of flammable, combustible, or explosive material may be present:

Class I	Flammable gas, vapor, or liquid
Class II	Combustible dust
Class III	Ignitable fibers or flyings

These classifications are described in NFPA standard 70, and in the NEC. As can be seen in Tables 46.1 and 46.2, the NEC includes classifications according to both the Division system and the Zone system.

Class I

Table 46.1 includes the NEC division and zone classification systems for Class I materials. In the division system, as shown on the left side of this table, hazardous areas are defined according to class, division, and group, and also include an auto-ignition temperature rating.

Class I Divisions The division indicates the likelihood of the material being present in an ignitable concentration. Division 1 means that ignitable mixtures may exist under normal conditions, or frequently, or where a fault that releases an ignitable mixture might also cause an electrical failure. Division 2 means that ignitable concentrations are not likely to be present under normal conditions, but can exist under fault conditions, or if the ventilation system fails.

Processes where flammable liquids are normally contained within a closed system, but could be released under a fault condition, can be classified as Division 2, rather than Division 1. Other areas where the presence of flammable gas is less likely can also be classified as Division 2. These include areas where a ventilation system prevents the accumulation of flammable gases or vapors, but failure of the ventilation system could result in an explosive environment. Areas adjacent to a Division 1 may be classified as Division 2 when positive pressure, physical barriers, or other means block the presence of flammable materials, as long as safeguards against failure of the prevention system are also included.

Class I Zones As with divisions, zones indicate the likelihood that the material will be present in an ignitable concentration, but the wording is somewhat different. Division 1 is replaced by zones 0 and 1. Zone 0 is where ignitable concentrations of flammable materials are likely to be present continuously, or for long periods of time, even under normal operating conditions. Zone 1 is where ignitable concentrations of flammable materials are likely to be present only intermittently under normal conditions, or during maintenance, or could be caused by a fault that might also cause an electrical failure. Zone 1 is also for areas adjacent to zone 0 areas. Zone 2 is where ignitable concentrations of flammable materials are not likely to be present under normal operating conditions, but if they do occur, they would be for only short periods of time.

Class I Groups The various types of gases, vapors, and liquids are sorted into groups according to their ignition energies (i.e., their ease of being ignited). In the table, the groups for the division system are A, B, C, and D, with A being the most easily ignitable. Representative gases are listed for each

TABLE 46.1
Class I Area Classifications

Class I—Flammable Gases, Vapors, or Liquids	
Divisions (NEC 500)	*Zones (NEC 505)*
Division 1—Ignitable concentrations may exist under normal conditions, or frequently, or where a fault might also cause electrical failure	Zone 0—Ignitable concentrations likely to be present continuously, or for long periods of time under normal conditions
	Zone 1—Ignitable concentrations intermittently under normal conditions, due to maintenance, etc., or where a fault might also cause electrical failure, or adjacent to zone 0
Division 2—Ignitable concentrations not likely to be present under normal conditions, but can exist under fault conditions, or if the ventilation system fails	Zone 2—Ignitable concentrations are not likely to exist under normal conditions, but if they do occur, they would be for short periods of time
Class I Groups	
(NEC 500)	*(NEC 505)*
Division 1 or 2	Zone 0, 1, or 2
A (acetylene)	IIC (acetylene)
B (hydrogen, etc.)	IIB + H_2
C (ethylene, etc.)	IIB (ethylene, etc.)
D (propane, etc.)	IIA (propane, etc.)
Class I Temperatures	
(NEC 500)	*(NEC 505)*
Division 1 or 2	Zone 0, 1, or 2
T1 ≤ 450°C	T1 ≤ 450°C
T2 ≤ 300°C[a]	T2 ≤ 300°C
T3 ≤ 200°C[a]	T3 ≤ 200°C
T4 ≤ 135°C[a]	T4 ≤ 135°C
T5 ≤ 100°C	T5 ≤ 100°C
T6 ≤ 85°C	T6 ≤ 85°C

[a] Additional Division 1, 2 temperatures (°C): T2A ≤ 280, T2B ≤ 260, T2C ≤ 230, T2D ≤ 215; T3A ≤ 180, T3B ≤ 165, T3C ≤ 160; T4A ≤ 120.

group in the table: Group A—acetylene, Group B—hydrogen, Group C—ethylene, and Group D—propane. A full listing of the classified gases and vapors is available in NFPA 497 (www.nfpa.org/catalog/product.asp?pid = 49704).

The groupings for the zone system are similar, but with A, B, C in the reverse order, as shown in the table. Group A is not shown because it is reserved for "firedamp," which is a gas mixture typical of mine environments, and is not covered by the NEC. Firedamp is a mixture of gases, having a primary component of methane.

Class I Temperature Rating The auto-ignition temperature ratings for the division system and the zone system in the NEC are the same, except that there are subparts with the division system, also shown in the table.

Classes II and III

Classification information regarding Class II (combustible dusts) and Class III (fibers and flyings) is provided in Table 46.2. Ignitable mixtures of fibers or flyings suspended in air should be considered as Class II. Fibers and flyings that are not air-suspended, for example, layers built up within or on equipment, etc., are considered as Class III.

Class II, III Divisions The definition of Division 1 for Class II and III is similar to that listed previously for Class I, except that Division 1 adds areas having electrically conductive dusts, and Class III includes areas for producing or processing fibers or flyings.

The definition of Division 2 for Class II and III is similar to that listed previously for Class I, except that with Class III, Division 2 can apply for storage areas, but not for processing areas.

Class II, III Zones Class II and III zones are equivalent to the zone definitions for Class I materials, except they are named zones 20, 21, and 22, instead of zones 0, 1, and 2, respectively.

Class II, III Groups As with Class I, the Class II and III groups also categorize the flammable materials according to

TABLE 46.2

Class II, III Area Classifications

Class II—Explosive Dusts (Class III Fibers and Flyings)

Divisions (NEC 500)	*Zones (NEC 505)*
Division 1—Ignitable mixtures may exist under normal conditions, or frequently, or where a fault might also cause electrical failure. Areas having electrically conductive dusts (for Class III, producing or processing the fibers or flyings)	Zone 20—Ignitable concentrations likely to be present continuously, or for long periods of time under normal conditions Zone 21—Ignitable concentrations intermittently under normal conditions, due to maintenance, etc., or where a fault might also cause electrical failure, or adjacent to zone 0
Division 2—Ignitable concentrations not likely to be present under normal conditions, but can exist under fault conditions, or if the ventilation system fails (for Class III storage, but not processing areas)	Zone 22—Ignitable concentrations are not likely to exist under normal conditions, but if they do occur, they would be for short periods of time

Class II Groups

NEC 500	*NEC 506*
Division 1 or 2	Zone 0, 1, or 2
E (metal dust)	N/A
F (carbonaceous dust)	D
G (nonconductive dust)	D
Class III (fibers and flyings)	D

Class II or III Temperatures

NEC 500		
Class II	*Class III*	*NEC 506*
T1 ≤ 450°C	No temperature marking. Temperature with maximum dust layer must not be greater than 120°C for overloading, or 165°C if not subject to overloading	Temperature is determined with a maximum dust layer, and is indicated as T°C (e.g., T120°C). The temperature must not be greater than the dust layer or cloud ignition temperature
T2 ≤ 300°C[a]		
T3 ≤ 200°C[a]		
T4 ≤ 135°C[a]		
T5 ≤ 100°C		
T6 ≤ 85°C		

[a] Additional Class II temperatures (°C): T2A ≤ 280, T2B ≤ 260, T2C ≤ 230, T2D ≤ 215; T3A ≤ 180, T3B ≤ 165, T3C ≤ 160; T4A ≤ 120.

their ignition energies. Types of materials listed in the division system include: Group E—metal dust, Group F—carbonaceous dust, Group G—nonconductive dust. Fibers and flyings are classified as Class III, with no group. In the zone system, they are all labeled as group D, except there is no separate grouping for metal dust (but metal dust is called group D in the equivalent section according to IEC). A full listing of the classified dusts, fibers, and flyings is available in NFPA 499.

Class II, III Temperature Rating The auto-ignition temperature ratings for the division system are the same for Class II as for Class I. It can be possible for combustible dust to accumulate on or around electrical equipment, possibly reducing its normal rate of thermal dissipation. The electrical equipment might then become capable of igniting the dust under normal or fault conditions. So, for Class II, the temperature class is determined with the maximum amount of dust layer on the equipment. For organic dust that may dehydrate or carbonize, the temperature class cannot be above 165°C.

For Class III, the temperature with the maximum dust layer possible must not be greater than 120°C if it is subject to overloading, or not greater than 165°C if it is not subject to overloading. With the zone system, the temperature rating is determined with a maximum possible dust layer, and the temperature attained must not be greater than the dust layer or cloud ignition temperature.

HAZARDOUS AREA EQUIPMENT

Once the area has been classified, the system must be designed, equipment specified, and installed. Some of the major technologies for use in hazardous areas for protecting electrical equipment against ignition of flammable materials include explosion proof, IS, and purging.

Explosion Proof

When electrical equipment is placed within an explosion proof housing, any ignition that may take place within the housing is prevented from being capable of igniting the atmosphere outside of the housing. It is assumed to be possible for flammable gases or vapors to enter the housing, and even for their ignition to be caused by the equipment within the housing. But the housing is designed to withstand the resulting explosion pressure without damage and to be able to release the resulting hot gases safely after they have been cooled to below the ignition temperature of the environment outside of the housing. The cooling is accomplished either along the threads of the housing cover, and/or out through a flamepath formed between two closely spaced parallel surfaces as shown in Figures 46.1 and 46.2.

As the products of combustion pass along the threads between the cover and housing (or between the thread of a conduit pipe and the thread of a mating hole in the housing), they are cooled to below the ignition temperature of the outside environment.

In Figure 46.2, the products of combustion are cooled as they pass between the parallel surfaces of the flamepath, such that they are cooled to below the ignition temperature of the outside environment.

When an explosion proof housing is larger than a typical junction box, it is required that a seal be installed in series with each conduit pipe that is attached. The seal must be within 18″ of the housing. This ensures that higher pressures that may be contained within the larger housing will not damage the conduit system or cause propagation of hot gases along the conduit system. It also ensures that pressure from a long run of conduit will not cause the rated explosion pressure of the housing to be exceeded. The sealing device typically used is called a pour-seal. After the wiring is routed, and before commissioning the system, a sealing liquid is poured into the pour-seal through an opening provided for this purpose. Then the sealing liquid hardens, and is capable of withstanding high pressure and preventing propagation of hot gases as in Figure 46.3. Another seal may be required at the boundary from a Division 1 area if the last seal is more than a few feet from the boundary, or if there are any fittings between the last seal and the boundary.

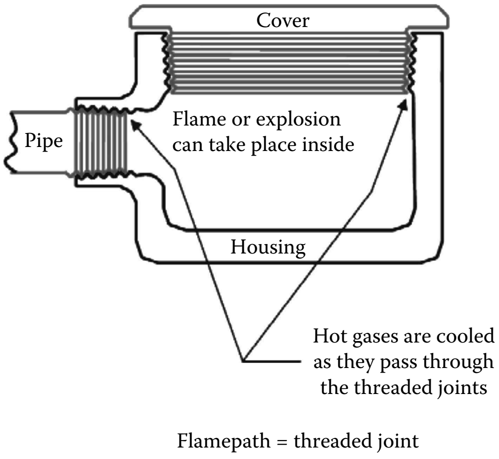
Cover
Pipe
Flame or explosion can take place inside
Housing
Hot gases are cooled as they pass through the threaded joints
Flamepath = threaded joint

FIG. 46.1
Flamepath along a threaded joint of an explosion proof housing.

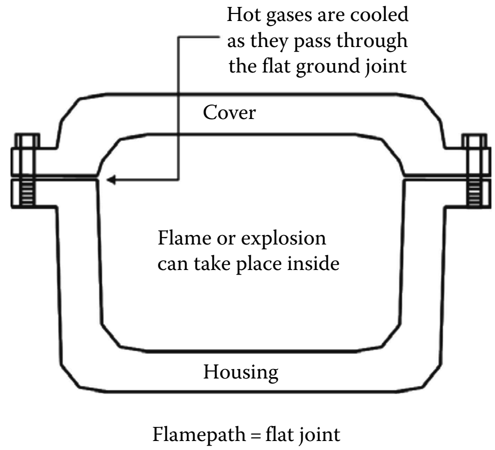
Hot gases are cooled as they pass through the flat ground joint
Cover
Flame or explosion can take place inside
Housing
Flamepath = flat joint

FIG. 46.2
Flamepath along a flat ground joint of an explosion proof housing.

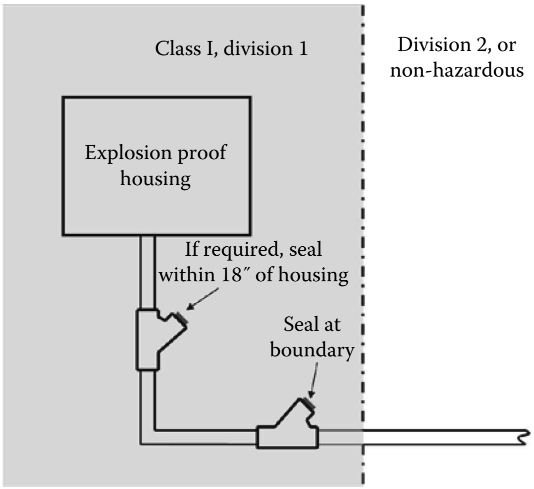
Class I, division 1
Division 2, or non-hazardous
Explosion proof housing
If required, seal within 18″ of housing
Seal at boundary

FIG. 46.3
Adding sealing devices (pour-seals) along a conduit run.

Intrinsically Safe

With intrinsically safe equipment, the energy available in the hazardous area is limited so that any spark generated will be below the energy required to ignite the specified type of atmosphere. This is normally done by inserting an approved IS barrier device in series with the wiring between the safe area and the hazardous area, with the barrier device being located in the safe area or within an explosion proof housing or purged enclosure. In addition, the equipment mounted in the hazardous area, and wired to the barrier devices, must be rated as IS for the classified area. An IS-rated piece of equipment, such as a two-wire 4–20 mA (milli ampere) transmitter, has been designed and approved to have a limited capability

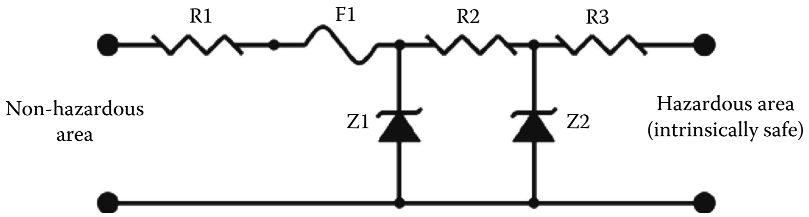

FIG. 46.4
Representative schematic of a passive (Zener) barrier.

to store energy, and such that the highest temperature of any component or spot (i.e., hotspot) is below its listed temperature rating.

The least expensive type of IS barrier device is the passive (Zener) barrier, a schematic of which is shown in Figure 46.4.

In this circuit, the left side is in the non-hazardous area, and may be, for example, exposed to the possibility of a short to line voltage. So, even if the left side is shorted to line voltage, wiring connected to the right side will not be subjected to energy levels above that appropriate for the rated environment. The purpose of resistor R1 is to limit the current through fuse F1 and Zener diode Z1 when there is a short to line voltage, for example, to a sufficiently low amount so that F1 will open before any damage can be done to Z1 (i.e., due to excessive current). Z1 then limits the voltage available to the right side of the barrier. Z2 functions the same as Z1 and is included for redundancy. R2 is included to isolate Z1 from Z2 so that the barrier can be tested to ensure that Z1 and Z2 are both operable. R3 serves to limit the current to the right side of the barrier, given the voltage that was already limited by the Zener diodes. Therefore, the voltage and current to the right side of the barrier are both limited, thus limiting the power available. In addition, any IS-approved device that may connect to the right side of the barrier must be limited in capacitance and inductance, so that energy storage capability is also limited.

Besides passive type barriers, there are also active barriers, which may include more complex electronic circuits. Active barriers can be used to enable communication over HART or other signal or data communication channels, to reduce loop resistance, or to act as a repeater.

IS products that will be located in a hazardous area can be approved under one of two concepts: entity approval or loop approval. With the entity approval concept, the approval for a device specifies the parameters that a barrier must meet in order to be used to protect that device (i.e., maximum voltage, current, capacitance, inductance, etc.), and any other product that may be approved for use with the device. With the loop concept, the approval for a device specifies the exact part number and products to be used in the loop, with no deviations being allowed. It is usually more convenient for a user to implement devices having the entity approval, because it allows some freedom to choose the barriers and products most appropriate for the particular application. But with some types of devices, it can be more difficult or more expensive to design for entity approval, so they may only be available with loop approval.

PURGING

Although there is not a definition of various types of purge and pressurization equipment in the NEC, it is a protection technique that is recognized in the NEC. For information about purging, the NEC refers to the NFPA standard 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

Purging is the process of supplying enclosures with compressed air or inert gas at a required flow and pressure in order to reduce the hazardous gas inside the enclosure to a safe level. It is a method for reducing the hazardous area classification within the purged enclosure. Sometimes it is more feasible or economical to use a purging system instead of explosion proof or IS systems. With a purging system, hazardous gases or vapors are diluted sufficiently so that they are below the LEL and therefore cannot be ignited. This can be done by a flow of clean air (i.e., air without flammable gases or instrument air), an inert gas (such as nitrogen), or sometimes can be from other sources of nonflammable gas. There are three types of purge systems (types X, Y, and Z), which have been in use in the United States, but only two of them are recognized in NFPA 496, which are the types X and Y.

A type X purging system can reduce the classification within the purged enclosure from Division 1 environment to nonhazardous. A type Y purging system can reduce the classification within the enclosure from a Division 1 environment to a Division 2 environment. With type X purging, electrical power is not applied until after the enclosure has been purged and a static pressure or flow is maintained. The purging flow is controlled by a timer, and the pressure or flow is monitored by a pressure or flow sensor. When the timer times out, and if the required pressure or flow is indicated, then electrical power is applied to the equipment (usually by a relay). If the pressure or flow is lost at any time thereafter, the relay opens and electrical power is removed as in Figure 46.5.

For type Y purging, the equipment to be purged must be already rated for a Division 2 environment. Instead of a timer, the purge time can be controlled manually, usually by

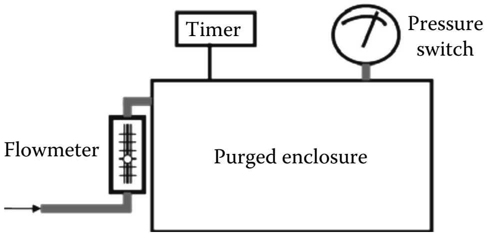

FIG. 46.5
Pictorial of a typical type X purging system.

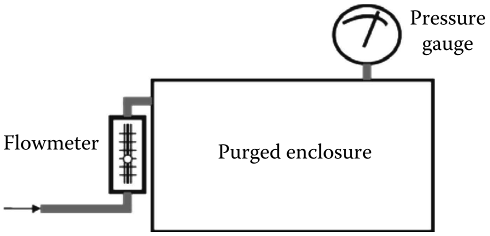

FIG. 46.6
Pictorial of a typical type Y purging system.

observing a flow meter while waiting for the time period to elapse. After the purge time, the enclosure is maintained at a positive pressure, which must be indicated or have an alarm. If a loss of pressure is indicated or alarmed, the proscribed actions can be taken manually, for example, turn off the power (see Figure 46.6).

Although type Z purging is not recognized in NFPA 496, it is for the purpose of reducing a Division 2 area to nonhazardous, and functionally operates in a similar way to type Y.

COMBUSTION TRIANGLE

Three things are required in order to support combustion (or conflagration, explosion, etc.): Fuel, oxygen, and a source of ignition. This is commonly shown as the combustion triangle, as depicted in Figure 46.7.

In order to avoid the possibility of completing the combustion triangle (and thus avoiding the risk of fire or explosion), at least one of these three elements must be removed from the equation.

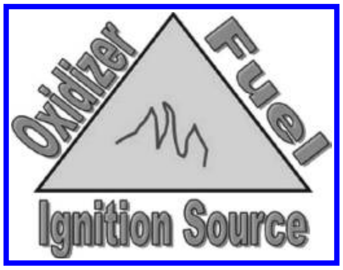

FIG. 46.7
The combustion triangle.

With an explosion proof housing, the possible ignition source within the housing is prevented from communicating to the environment outside the housing, so explosion proofing removes the ignition source. With IS, energy and temperature are limited to below that required to ignite the atmosphere. So, IS also removes the source of ignition. Purging, however, instead removes the flammable material by diluting it below the mixture concentration needed to support combustion. This removes the fuel portion of the combustion triangle. Some purging systems, however, may use nitrogen or other gas with little or no oxygen, instead of air for the purging. These systems, commonly called "inerting systems" reduce the oxygen concentration below that needed to support combustion, so they remove the oxidizer of the combustion triangle. They are useful within equipment such as paint or ink mixers, pharmaceutical centrifuges, etc., in which it is not possible to avoid presence of the flammable material, and the possibility of ignition due to static electricity (that can be generated by the moving equipment, in combination with products having high electrical resistance) exists. With the oxygen concentration controlled to below that needed for combustion (usually in the 0.5%–4% range, depending on the solvent, etc.), the oxygen component of the combustion triangle is removed.

APPLICABLE DOCUMENTS

There are many sources of information regarding electrical equipment for use in hazardous areas. Table 46.3 lists some of the NFPA document numbers and names that may be useful in classifying hazardous areas. Table 46.4 lists some of the numbers and names of articles of the NEC that may also help.

CONCLUSIONS AND COMMENTS

Many industrial fires and explosions around the world have been documented over the years. These first led to the recognition of the cause of the problems, and then to the formulation of preventive measures. This eventually resulted in the establishment of safety rules and regulations that address the potential hazards of working with flammable materials. In North America, the NEC is the accepted standard. Products for use in hazardous areas must be approved by an accepted approval agency, such as Factory Mutual, Underwriters Laboratories, or the Canadian Standards Association. Before installing electrical equipment in an area that may contain flammable mixtures of gases, vapors, liquids, dusts, fibers, or flyings, it is necessary to classify the area according to the likelihood of the flammable mixture being present, the type of flammable material, and the minimum ignition temperature. Once the area has been thus classified, then suitable and safe equipment can be specified and installed.

TABLE 46.3
Some of the Many NFPA Documents Regarding Hazardous Areas

NFPA #	*Document Name/Description*
30	Flammable and combustible liquids code
33	Standard for spray application using flammable or combustible materials
34	Standard for dipping and coating processes using flammable or combustible liquids
35	Standard for the manufacture of organic coatings
36	Standard for solvent extraction plants
45	Standard for fire protection for laboratories using chemicals
50-A	Standard for gaseous hydrogen systems at consumer sites
50-B	Standard for liquefied hydrogen systems at consumer sites
51	Standard for design and install. Of oxygen-fuel gas systems for welding, cutting, and allied processes
58	Liquefied petroleum gas code
59	Standard for storage and handling of liquefied petroleum gas at utility plants
59A	Standard for the production, storage, and handling of liquefied natural gas
61	Standard for prevention of fires and dust explosions in agricultural and food processing facilities
70E	Hazardous areas
86C	Standard for industrial furnaces using a special processing atmosphere
122	Standard for fire prevention and control in metal/nonmetal mining and metal mineral processing facilities
325	Guide to fire hazard properties of flammable liquids, gases, and volatile solids
328	Recommended practice for control of flammable and combustible liquids and gases in manholes, sewers, etc.
329	Recommended practice for handling releases of flammable and combustible liquids and gases
385	Standard for tank vehicles for flammable and combustible liquids
386	Standard for portable shipping tanks for flammable and combustible liquids
395	Standard for the storage of flammable and combustible liquids at farms and isolated sites
400	Hazardous materials code
469	Standard for purged and pressurized enclosures for electrical equipment
480	Standard for storage, handling, and processing of magnesium solids and powders
481	Standard for production, processing, handling, and storage of titanium
482	Standard for production, processing, handling, and storage of zirconium
484	Standard for combustible metals
485	Standard for production, processing, handling, and storage of lithium metal
496	Standard for purged and pressurized enclosures for electrical equipment
497	Rec. prac. for classif. flam. liq., gas or vapor and haz. loc. for elec. inst. in chem. proc. areas
499	Rec. prac. for classif. of comb. dusts and of haz. locs. for elect. install. in chem. proc. areas
650	Standard for pneumatic conveying systems for handling combustible particulate solids
654	Standard for the prev. of fire and dust explosions from mfg., proc. and handl. of combust. partic. solids
664	Standard for prevention of fires and explosions in wood processing and woodworking facilities
806	Perform.-based standard for fire prot. for advanced nuclear reactor electric generating plants
820	Standard for fire protection in wastewater treatment and collection facilities

TABLE 46.4

Some of the Articles of the NEC Regarding Hazardous Areas

NEC Article #	*Description*
500	Hazardous (classified) locations, Classes I, II, and III, Divisions 1 and 2
501	Class I locations
502	Class II locations
503	Class III locations
504	Intrinsically safe systems
505	Class I, zones 0, 1, and 2 locations
506	Zones 20, 21, and 22 locations for combustible dusts or ignitable fibers/flyings
510	Hazardous (classified) locations—specific
511	Commercial garages, repair, and storage
513	Aircraft hangars
514	Motor fuel dispensing and service stations
515	Bulk storage plants
516	Spray application, dipping, and coating processes
517	Health care facilities

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